eters of the channel, the acoustic transducer **414** generates a resonant standing wave within the fluid, creating one or more zones of minimal pressure amplitude (acoustic nodes) toward which particles are driven. The forces that particles experience are dependent on particle size; therefore, the largest particles **420** move toward the node **424***b* fastest. Positioning the node **424***b* within the recovery fluid **408** stream allows the largest particles **420** to be carried out of the chip **416** with the recovery fluid **408**, separating them from other sample components that remain in the sample **412** stream.

Referring now to FIG. **4**B, a cross section taken along lines **4**B of FIG. **4**A in the direction of the arrows is shown. The body of the chip **416** includes a glass cover plate **426**. The body of the chip **416** and the glass cover plate **126** enclose the bypass fluid channel **404**, the bypass fluid **402**, the recovery fluid **408**, and the sample fluid **412**. The acoustically transparent wall **422** maintains the bypass fluid **402** separate from the recovery fluid **408**.

The acoustic transducer **414** produces the acoustic nodes **424***a* and **424***b*. The first node **424***a* is located in the recovery fluid **408** stream so that the recovery fluid **408** receives the large particles **420** that are concentrated at the first acoustic node **424***a* causing them to be carried by the recovery fluid **408** out of the "large particle" outlet (LPO) **430**. The second node **424***b* is located in the bypass channel and does not participate in the separation.

Example 4

Use of a Gel to Modify the Separation Channel Geometry

Referring now to the drawings and in particular to FIG. **5**A, another embodiment of the invention is illustrated wherein the stream of concentrated particles is positioned off-center in the fluid channel by means of a region of hydrogel adjacent the fluid channel. In this embodiment, rather than using a second fluid channel separated by a wall, a hydrogel is immobilized (by photopolymerization or by other means) within the searation channel. The ultrasound standing-wave pressure fields are optimized to transfer focused particles out of the sample stream and into the recovery fluid within the recovery fluid channel. The piezoelectric transducer may be driven at single or multiple frequencies to achieve the optimal node placement depending on the channel and wall geometry. In addition, multiple small piezoelectric transducers may be arranged to produce different sound fields in different regions of the chip.

The embodiment illustrated in FIG. **5**A is designated generally by the reference numeral **500**. The device **500** has an "H-filter" geometry in which two fluids are pumped side-by-side down a microfluidic separation channel with two inlets and two outlets. One of the two fluids, the sample fluid **512**, contains the sample and the other fluid is a "recovery" buffer **508**, which is an appropriate medium (water or buffer) into which focused particles are transferred, while the unfocused components remain in the sample and continue straight through the system. Channel depth (typically 100-300 micrometers), width (typ. 300-1000 micrometers), and wall thickness (typ. 10-40 micrometers) are determined for each chip based on the desired acoustic pressure fields, and fabricated by means of standard photolithography with anisotropic etching. The two fluids enter the separation channel through separate inlets, and the separated sample fractions are collected at the two outlets.

The present invention provides an ultrasonic microfluidic apparatus for separating small particles **518** from large particles **520** contained in the sample fluid **512**. A sample input channel **510** is provided for conveying the sample fluid **512** containing small particles **518** and large particles **520** toward the separation area. A recovery fluid input channel **506** containing recovery fluid **508** is routed to convey the recovery fluid substantially parallel and adjacent the sample fluid. Within the separation channel, the recovery fluid contacts the sample fluid **512**. A gel **502** is located substantially parallel and adjacent the separation channel **506**. The gel **502** comprises an acoustic extension structure.

An acoustic transducer **514** in contact with the microfluidic chip **516** produces an ultrasound pressure field throughout these fluids. Properly tuned to match the geometric parameters of the channel, the acoustic transducer **514** generates a resonant standing wave within the fluid, creating one or more zones of minimal pressure amplitude (acoustic nodes) toward which particles are driven. The forces that particles experience are dependent on particle size; therefore, the largest particles **420** move toward the node **424** fastest. Positioning the node **524** within the recovery fluid **508** stream allows the largest particles **520** to be carried out of the chip **516** with the recovery fluid **508**, separating them from other sample components that remain in the sample stream.

Referring now to FIG. **5**B, a cross section taken along lines **5**B of FIG. **5**A in the direction of the arrows is shown. The body of the chip **516** includes a glass cover plate **126**. The body of the chip **516** and the glass cover plate **126** enclose the gel **528**, the recovery fluid **508**, and the sample fluid **512**. The acoustic transducer **514** produces the acoustic node **524** in the recovery fluid stream **506** so that the recovery fluid **508** receives the large particles **520** that are concentrated at the acoustic node **524** causing them to be carried by the recovery fluid **508** out of the "large particle" outlet (LPO) **530**.

While the invention may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.

The invention claimed is:

1. An ultrasonic microfluidic apparatus for separating small particles from large particles contained in a sample fluid, comprising:

a sample input channel for channeling the sample fluid containing the small particles and the large particles;

a recovery fluid input channel containing recovery fluid, routing said recovery fluid to flow substantially parallel and adjacent to the sample fluid, wherein said recovery fluid contacts the sample fluid;

an acoustic transducer that produces

an acoustic standing wave, that generates a pressure field having at least one node of minimum sound pressure amplitude; and

an acoustic extension structure located proximate the sample fluid and said recovery fluid that positions said at least one acoustic node in said recovery fluid concentrating the large particles in said recovery fluid wherein said acoustic extension structure includes a gel located proximate the sample fluid and said recovery fluid positioning said at least one acoustic node in said recovery fluid concentrating the large particles in said recovery fluid.

2. The ultrasonic microfluidic apparatus for separating small particles from large particles contained in a sample fluid